

Art-Integration through Making

Dioramas of Women Mathematicians' Lives Enhances Creativity and Motivation

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Abstract

Creativity is essential for solving problems in the workplace, natural environment, and everyday life, necessitating that creativity be nurtured in schools. Identification of factors that intrinsically motivate students to learn difficult or initially unappealing content is also important. This project, in which 24 racially diverse fifth grade girls created dioramas of the lives of diverse successful women mathematicians, explored the girls' reactions to art integration into mathematics through a phenomenological qualitative analysis of their products, essays, and responses to questionnaires. The project supported the Next Generation Science Standard for engineering design, Standard 3-5-ETS1-1 and two National Core Arts Standards for visual arts for fifth grade students, VA:Cr2.1.5a and VA:Cr2.2.5a. The students evidenced positive studio habits, including task focus and longterm persistence, expression of strong personal meaning, and acquisition of new art techniques. The most frequent theme of students' responses was their surprise and delight that art and mathematics can be connected. The diorama construction work was viewed as intrinsically motivating because the creative aspects of the project allowed students to stretch their skills, learn new art techniques of spatial construction, and to experience *flow* as they became absorbed in their work. The arts-integrated and studio nature of this project promoted creative production and accompanying intrinsic motivation, allowing students to become eager to learn both information about mathematics careers and three-dimensional art techniques.

Keywords

Art-integration, female mathematicians, intrinsic motivation, mathematics, STEM education, STEAM education

Introduction

Creativity has been recognized as a significant 21st century skill needed for solving global problems in many areas, including economics, environment, health, public policy, and everyday living (Moran, 2010). Preparing today's students to think and perform creatively is important.

A meta-analysis of 15 papers with 26 independent samples of 6,435 adult and child participants (de Jesus, Rus, Lens, & Imaginário, 2013) showed a significant positive relationship between intrinsic motivation and creativity related to producing a product. Intrinsic motivation can be defined as "the enjoyment of and interest in an activity for its own sake (Linton, 2014, p. 1). This result of creativity and intrinsic motivation being connected was repeated in the results of a correlational study of inventories measuring creativity, happiness, various types of motivation, and stress administered to 420 college students (Ceci & Kumar, 2016) that showed a very strong relationship between creativity and intrinsic motivation. This study (Ceci & Kumar, 2016) also indicated that stress from creative pursuits was strongly

correlated with extrinsic motivation, significantly correlated with final product orientation, and negatively correlated with intrinsic motivation. The Composite Creative Capacity Score was strongly correlated with three styles of creativity: use of techniques, belief in unconscious processes, and use of the senses (Ceci & Kumar, 2016). This means that creative students are intrinsically motivated and process-oriented; they tend not to be extrinsically motivated or overly concerned with the final product. Teaching students new techniques, encouraging them to play and allow ideas to rise to conscious awareness, and to use their senses to produce an aesthetic product can have a positive effect on motivation and creativity.

Consequently, identification of factors that intrinsically motivate students is important (Amabile, 1996; Jaquith, 2011). Teachers with knowledge of motivation factors can center creative instructional activities around them. "Intrinsic motivation should be at the forefront of any conversations about creativity in schools" (Jaquith, 2011, p. 15). Intrinsic motivators such as personal interest and curiosity are closely connected to creativity (Csikszentmihalyi, 1996; Hetland, Winner, Veenema, & Sheridan, 2007; Runco, 2007).

The current study focuses on identifying the aspects of a diorama-making project, highlighting the lives and accomplishments of diverse women mathematicians, that students found to be motivating. The goals of this project were: 1) to raise student awareness of the significant professional roles diverse contemporary women are playing in mathematics, thereby breaking through stereotypes of gender and race; 2) to provide successful role models for girls concerning mathematics careers, along with strategies for dealing with obstacles; 3) to engender a growth mindset regarding mathematics with persistence and appreciation of how mathematics enters so many facets of life; and 4) to provide practice in three-dimensional construction and spatial thinking skills because spatial thinking skills form a gateway to STEM (Science, Technology, Engineering, and Mathematics) careers (Uttal & Cohen, 2012). Diorama construction was chosen for this project as a meaningful way of integrating the arts and spatial thinking with mathematics. The benefits of arts integration are explored in the following literature review.

Benefits of Arts-Integration

There are three main arguments for the benefits of arts integration into the curriculum. Each of these are explored in this review of the literature.

Dispositions and Habits Taught through the Arts

The first argument for arts integration is that the arts assist students in developing valuable dispositions or habits (e.g., Gibson, 2003; Hetland, Winner, Veenema, & Sheridan, 2007; Winner, Hetland, Veenema, Sheridan, Palmer, & Locher, 2006; Root-Bernstein & Root-Bernstein, 1999, 2013). Art and craft activities support mental dispositions such as practicing and persevering, along with trial-and-error problem solving (Root-Bernstein & Root-Bernstein, 2013). The arts provide novel structures, methods, and analogies that can stimulate innovation in other domains (Root-Bernstein & Root-Bernstein, 2013). Developing creative thinking skills in one discipline (art) helps students understand how to initiate and continue creative thinking in other disciplines (Root-Bernstein & Root-Bernstein, 1999).

Students who are taught in studio art classes learn eight habits of mind that allow them to succeed in these classes and that likely transfer to other domains. These habits (Hetland et al., 2007) are: 1) developing a sense of which tools and materials to choose for a particular project and what criteria to use for those decisions; 2) persisting in work for a sustained period of time through focus and inner-directedness; 3) generating or envisioning mental images of possibilities; 4) expressing strong personal meaning through the work; 5) reflecting upon and explaining reasons for different aspects of the work; 6) evaluating what does and does not work in various aspects of one's own work and that of peers; 7) stretching skills and exploring new techniques and ideas; and 8) understanding the art world in its history, domain, communities, and collaborative interactions. The arts and engineering also share the design process with many steps in common such as defining a problem, researching, generating ideas and possible solutions, creating prototypes, presenting to an audience and refining to create the final solution (Bequette & Bequette, 2012).

Arts integration, if well taught, is likely to make school more engaging and motivating for students. Barbara Ischinger wrote in the foreword of the book *Art for art's sake? The impact of arts education* (Winner, Goldstein, & Vincent-Lancrin, 2013), "...[T]here is far too little research on the impact of arts education on student outcomes of creativity critical thinking, persistence, motivation, and self-concept, and this prevents us from making strong conclusions about these outcomes" (p. 3). Although the current study explores this problem, there are a couple of recent studies that support arts integration as highly engaging. A study of a low-performing middle school that implemented an arts-integration model showed that, in addition to student achievement rising 20%, student attitudes were much improved as evidenced by a 77% decline in discipline referrals (Snyder, Klos, & Grey-Hawkins, 2014). Another recent study (Li, Kenzy, Underwood, & Severson, 2015) showed dramatic positive changes in behavior, motivation and academic achievement for at-risk students when an arts-based curriculum was introduced.

Arts integration may inspire students toward inner growth and self-actualization through creative projects. Scholars studying creativity first concentrated on the personalities of exceptionally creative persons (e.g., Gough, 1979) and, secondly, the cognitive or mental processes involved in creative production; the third wave examined social and cultural contexts of groups (Sawyer, 2012; Zhou, 2003). A fourth wave of study assumed a transpersonal perspective that was founded on aspirations of inner growth (Linton, 2014). Intrinsic motivation contributed to absorption with an intensity of awareness and accompanying joy through engagement in the activity (Linton, 2014). This joy is related to Maslow's peak experience (1968) and Csikszentmihalyi's *flow* (1990). Individuals pursue tasks and situations that support their interests and in which peak experiences or flow can be achieved (Sawyer, 2012). Intrinsic motivation is therefore an integral component of creativity that can act as a transcendent function toward self-actualization (Linton, 2014).

Enhancement of Learning in Non-Art Domains

The second argument for arts integration is that the arts enhance learning in other domains. Arts and crafts work helps students develop skills in STEM domains such as

observation (attending to detail while sketching, painting, sculpting, or modeling), visual thinking (transforming ideas into pictures, symbols, storyboards), pattern recognition and transformation, and manipulative ability as students handle paint brushes, use sculpting tools, glue securely and neatly, or weave fibers (Root-Bernstein & Root-Bernstein, 2013). Another skill area addressed both in the arts and in STEM subjects is spatial thinking, referring to perception, visualization, and orientation of objects in space, along with the tools of representation and processes of reasoning (Committee on Support for Thinking Spatially, 2006). Many studies have confirmed that spatial thinking is central to success in STEM fields (Newcombe, 2010; Wai, Lubinski, & Benbow, 2009). Spatial skills predict who will enter STEM fields because they help students better understand and manipulate early-encountered difficult STEM content whereas STEM experts have the depth of knowledge to bypass many spatial skills that novices require (Uttal & Cohen, 2012).

Increases in Knowledge Retention

The third area concerning benefits of art integration is knowledge retention. Eight mechanisms from cognitive psychology that are naturally a part of arts integration support longterm memory of content (Rinne, Gregory, Yarmolinskaya, & Hardiman, 2011). These mechanisms are: 1) rehearsal or repetition of information as an artwork is created or as a dramatic script is readied for performance; 2) elaboration and adding of meaningful details; 3) generation of information in response to a cue; 4) enactment or physically acting out the content; 5) oral production or speaking the content out loud; 6) effort after meaning or expending the effort to try to understand new content or ideas such as lines of poetry or images in a painting; 7) emotional arousal; and 8) pictorial representation. As students engage in the arts, they naturally participate in actions that involve one or more of these psychological mechanisms. A controlled experiment comparing the longterm knowledge retention of fifth grade students who learned two different science topics with or without arts integration (Hardiman, Rinne, & Yarmolinskaya, 2014) showed that, after the lessons had concluded, students learning information under both conditions retained about the same amounts of content. However, two months after this

posttest, students were again re-tested and the students who had been taught information through arts integration retained significantly more content. The researchers identified their application of the eight different mechanisms in the arts-integrated conditions of the project.

The foregoing review of professional literature related to arts integration into other domains has shown many benefits. The area of student engagement and motivation has been noted as needing more investigation in 2013. Since that time a couple of studies have documented positive results for this beneficial aspect of arts integration. The current study further extends this research.

Method

This qualitative study examined the impact of art integration on students' intrinsic motivation in studying mathematicians and mathematics careers. Other aspects of this project focus on students' racial identities and aspects of a female mathematician or her life allowing students to feel a strong connection or inspiration are addressed in another article resulting from this same study (Rule, Atwood-Blaine, Edwards, & Gordon, in review).

Study Design and Research Questions

Following a phenomenological research design, we present a qualitative description of participants' overall lived experiences at the conclusion of the 8-month long project. We collected written responses to broad, open-ended questions at the end of every lesson. We also analyzed participants' written essays of most important ideas students learned and artistic products at the conclusion of the project. In addition, we collected anecdotal evidence through weekly observations throughout the project.

This research article focuses on the following questions:

1. How do students react to making the art-integrated diorama work?
2. What can be observed from the resulting student products?

3. How did studying the diverse, accomplished women mathematicians in an art-integrated manner affect student intrinsic motivation during the project?

Participants and Setting

This project was conducted at a low socio-economic public school in the Midwestern United States with 72.8% of the school population receiving free and reduced cost lunches. The racial make-up of the school was 55% White, 34% African American, 9% Hispanic, 1% Native American, and 1% Asian. Twenty-four fifth grade female students (12 White, 9 African American, 2 Hispanic, and 1 Asian) participated in the lessons. All students and parents provided written consent for student participation and for photography of students and their products.

The enrichment class in which the lessons were taught was organized as a studio classroom as described in Hetland et al. (2007). Each class, the teacher introduced concepts about the women mathematicians through a pictorial slide show. Concepts about an art technique were then introduced, demonstrated, and then examples were shown. Students then worked on their own, talking quietly as they implemented the new technique. A researcher was positioned at each table and discussed what students were doing, often commenting on, suggesting changes, or critiquing the work of each individual student.

National Standards Addressed by the Lessons

This project supported one of the Next Generation Science Standards (Achieve Inc., 2013) for engineering design, Standard 3-5-ETS1-1: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost. Students were given a diorama base, required to paint it using a gradient of color, and asked to cut out and arrange given images of women mathematicians and items related to their lives or careers into scenes. Students had time constraints of the class periods assigned to the project, given or chosen images, and choices of colored cardstock papers. They learned several spatial techniques of making a three-dimensional scenes or objects including: using stiff foam cubes to make some parts of the scene pop out; making a

folded and cut substructure so that a scene would pop up as a flap is pulled down; folding and gluing a net of 20 equilateral triangles with attached tabs to make an icosahedron; and folding images printed onto a rectangular prism net to make a desk, bookcase, or other item. These activities also supported the National Core Arts Standards for visual arts for fifth grade students (National Coalition for Core Arts Standards, 2014), standard VA:Cr2.1.5a: Experiment and develop skills in multiple art-making techniques and approaches through practice. Another visual arts standard supported was standard VA:Cr2.2.5a: Demonstrate quality craftsmanship through care for and use of materials, tools, and equipment. Students learned the art techniques of using acrylic paints to produce a gradient of color, techniques of applying glue to securely adhere images, and cutting out images with a smooth, narrow margin of white surrounding the image.

One Common Core Standard (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010) for geometry was specifically supported through the project: Represent three-dimensional figures using nets made up of rectangles and triangles, use the nets to find the surface area of these figures, and apply these techniques in the context of solving real-world and mathematical problems. As students made the three-dimensional icosahedrons and some of the items for scenes from nets, they applied nets to the real-world activity of making items for a diorama.

Lessons Conducted during the Project

Table 1 presents the lessons taught during this extended project and the integrated art activities. Six diverse women mathematicians and the mathematics of their jobs were highlighted during this project: Native American Pat Courtney Gold (computer coding, computer modeling), African American Gloria Ford Gilmer (Board of Governors of Mathematical Association of America, college teaching, Ethnomathematics), African American Kimberly Flagg Sellers (Associate Professor at Georgetown University in statistics), White American Mary Lee Wheat Gray (Mathematics and Statistics Professor American University), Asian American Fan Chung Graham (Professor University of California San Diego), and Hispanic American Ruth Gonzales (Computer coding, oil

exploration). A diverse set of women mathematicians was chosen to allow students to see that women of all races or ethnicities can be successful in mathematics.

Several of these women mathematicians had strong connections to art: Pat Courtney Gold was a fiber artist who wove traditional Wasco baskets with geometric designs; Gloria Ford Gilmer helped start the field of Ethnomathematics by studying the symmetry of braided hair styles; Fan Chung Graham painted water color scenes of the seashore and of famous mathematicians; and Ruth Gonzales collected Pre-Columbian Mexican art. The life and career of each woman mathematician was presented to students via a highly-pictorial electronic slide show. Information about the early life and career accomplishments was included; additionally, evidence for how the mathematician was a caring person or was involved with social justice issues was provided to counteract the stereotype of successful women in a traditionally male field being hard and cold (Heilman, Wallen, Fuchs, & Tamkins, 2004; Heilman & Okimoto, 2007).

The diorama bases that were made by the first author and supplied to the students are shown in Figure 1. Students did not start from scratch because of time constraints on the number of hours the researchers could have with students for the project. Two examples of icosahedron nets and one example of an assembled icosahedron are shown in Figure 2.



Figure 1. Example diorama bases painted with white gesso.

Table 1. *General Sequence of Approximately One Hour Lessons with Integrated Art Work*

Lesson #	Main Topic	Art Activities
1	Overview, distribution of diorama bases	Receiving Diorama base and investigating its hinged parts; Learning how the diorama base was made from cardboard cracker boxes, white craft glue, recycled copy paper, and white gesso
2	Painting of diorama interior	Mixing colors and creating gradients
3	Painting of diorama exterior	Mixing new colors and creating gradients
4	Pat Courtney Gold slide show; attaching mathematician's face	Learning to back images with cardstock to stiffen and creating a triangular prism to support the two sides of the mathematician's face images on the top of the diorama box
5	Gloria Ford Gilmer slide show; work on cutting out diorama images	Carefully trimming around images leaving a smooth margin of a couple of millimeters
6	Making the pop-up support for the back flap of the diorama	Learning how to fold cardstock and cut it to make a simple pop-up; gluing the pop-up structure to the back flaps of the diorama
7	Ruth Gonzales slide show; creating the interior scenes of the diorama	Learning to carefully coat images with glue and apply them to the diorama to make scenes; arranging images so that they fit
8	Kimberly Flagg Sellers slide show; creating the icosahedron	Folding the icosahedron net and applying glue to tabs to make a 3-D geometric figure
9	Mary Lee Wheat Gray slide show; working on the interior pop-out scenes	Using stiff foam cubes to support cardstock-mounted images so that they pop-out from the background scene
10	Fan Chung Graham slide show, begin work on essay	Reflection on most salient aspects of the project
-	School's Multicultural Fair: Dioramas (without back pop-up scene or essays) are displayed	Students showed their mostly-finished work to their families and experienced pride in their attractive dioramas
11	Live Internet video conference with Kimberly Flagg Sellers	No art activity
12	Complete essay	Choose appropriate and meaningful images to illustrate the essay in the pop-up scene
13	Finish pop-up scene and glue on essay	Completion of pop-up and diorama

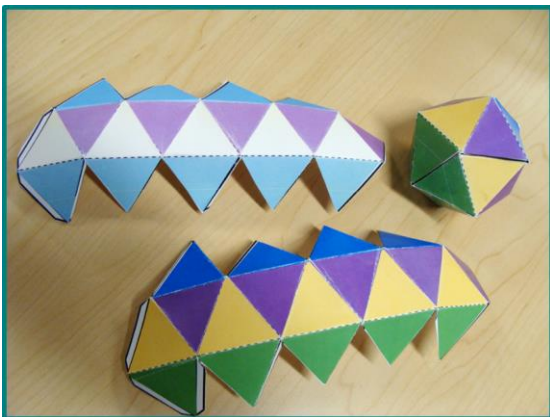


Figure 2. Two example colored icosahedron nets and a three-dimensional assembled icosahedron.

Data and Data Analysis

After students had studied a new woman mathematician, they were asked to write responses to three or four questions that asked what they admired or found interesting or found to be surprising about the woman and in what ways they were able to make a connection to the mathematician. Other questions asked students to describe what they enjoyed the most so far and any changes they might make to the project. The questions were varied somewhat to avoid students providing the same responses each time. Student responses to these questions and sentences from the essays they wrote near the end of the project about the most important things they learned were put into a spreadsheet with one complete idea (usually a sentence) on each line. Data were coded using the constant comparison method (Dye, Schatz, Rosenberg, & Coleman, 2000) to form general categories of themes. Spreadsheet sorting functions were used to manipulate the data. Each category was then again analyzed to discover major ideas related to that theme that emerged from the data.

Results and Discussion: Student Reactions and Student-Made Dioramas

Study results pertaining to the first two research questions on student reactions to the project and the characteristics of student diorama products are presented

here. In general, student reactions to the project were positive throughout the project's eight-month duration. Students focused intently on their diorama work and produced neat, attractive products. All eight of the studio habits of Hetland et al. (2007) were evidenced during the project as described in the following sections.

Early Reactions to the Project

Students were excited the first day when they saw the gesso-coated white cardboard diorama bases and the example dioramas made by one of the researchers. Students were asked to take a paper ticket with a number on it from the table. Students then located the diorama with the same number on it as their paper ticket. In this manner, the dioramas were assigned randomly. See Figure 1 for images of the six diorama bases. As the project unfolded, students tended to remain satisfied with the mathematician each had "chosen." Only one student ever commented that she wished she could have selected the woman for her diorama. Students seemed to appreciate the life and contributions of all of the spotlighted women mathematicians.

Dioramas of Native American Pat Courtney Gold

Figure 3 shows images of student dioramas that focused on mathematician Pat Courtney Gold. The front of the diorama was made with half of a small cylindrical oatmeal or hot cereal box attached in such a way over a cut-out rectangle that the interior of the cereal box was visible when the front of the diorama was opened like a book. This partly cylindrical feature on the front of the diorama was made into a cardboard replica of a Sally bag or Wasco basket, a tightly woven cylindrical basket of flexible dogbane and grasses that was used to store powdered dried salmon by the Wasco People of central Oregon (University of Oregon Museum of Natural and Cultural History, 2014). The various three-dimensional, hinged, and cut-out features of the dioramas allowed students to develop a sense of which tools, materials, and techniques to use for various spatial projects, as in Hetland et al.'s (2007) first studio habit.

In Figure 3, Pat's portrait sits atop the rectangular box of the diorama, framed by an image of the bottom of a Wasco basket. The portrait is still visible as the diorama is

opened, although some of the photos making up this image have been cropped and do not show her photo. The inside of the front is a scene of Pat's weaving studio with a three-dimensional bookcase, brick wall, and large basket. A shelf holds examples of Pat's Wasco baskets. A photo of Pat shows her weaving a basket. The facing three-dimensional scene shows Pat working for a computer firm, translating mathematical equations into computer code. The people in the scene are mounted on different thicknesses of foam so that the scene is three-dimensional. The back of the diorama shows a pop-up scene featuring the student's choice of photos of women mathematicians and an essay about what the

student learned from the project. One student put a photo of herself into Pat's house (Figure 3, bottom right image) because she liked Pat Courtney Gold and would like to visit her. Most students took great care in trimming around the various images for the dioramas, for example, the Wasco baskets on the shelf in the upper middle part of Figure 3 were neatly trimmed and carefully glued on the white shelf. Because students seldom had the opportunity to do much cutting or gluing, the trimming of images and application of them to the diorama stretched their skills, the seventh habit resulting from studio art programs (Hetland et al., 2007).



Figure 3. Example Views of Dioramas of Native American Mathematician Pat Courtney Gold

Dioramas of African American Gloria Ford Gilmer

Examples of student made dioramas focused on African American Gloria Ford Gilmer are shown in Figure 4. The front of the diorama of Gloria Ford Gilmer shows a large three-dimensional icosahedron, the symbol of the Mathematical Association of America (Mathematical Association of America, 2016). Gloria Gilmer was the first Black woman to serve on the board of governors of the Mathematical Association of America (Riddle, 1995-2016a). The front inside scene featured images of braided hairstyles with rotational and mirror symmetry. Several also showed tessellations made by the parts on the scalp. Gloria Ford Gilmer co-founded the field of Ethnomathematics in 1985 (Williams, 2008). She studied African American braided hairstyles, finding patterns of symmetry (Gilmer, 1998). Students decided where to place images to make the most visually-pleasing display. Often, they mentally envisioned

possible arrangements, then they cut out the images and placed the images in what they thought would be the optimal arrangement before gluing the images to the diorama. This corresponds to Hetland et al.'s third studio habit. The sixth studio habit of evaluating what does and does not work was also applied here.

The facing inside scene shows Gloria at the traditionally Black college she attended, Morgan State University. Note that a pop-up scene on the back of the diorama in the lower right part of Figure 4 shows a White student next to photographs of Fan Chung Graham and Gloria Ford Gilmer. At this school with a highly diverse student population, students seemed to make connections and form friendships across racial lines. Although Hetland et al.'s (2007) eighth studio habit was about communities in the art world, the students in this study learned about communities in mathematics and developed a greater respect for women mathematicians of different races.



Figure 4. Student-made dioramas featuring Gloria Ford Gilmer

Dioramas of Hispanic American Ruth Gonzalez

Several example dioramas featuring successful mathematician Ruth Gonzalez are shown in Figure 5. Students chose bright, cheerful colors for their dioramas. They learned the new technique of mixing two colors of paint on a tray to create a gradient for more depth and visual appeal. This corresponds to the seventh studio habit mentioned by Hetland et al. (2007).

The front of the diorama shows the Exxon Building in Houston. Ruth worked as geophysical mathematician at Exxon (now ExxonMobil), turning data from seismic exploration of oil and gas basins into three-dimensional views of the rocks deep beneath the surface (Riddle, 1996-2016b).

The front inside scene shows a map of Mexico surrounded by prehistoric Mexican clay sculptures and pottery. This scene alludes to Ruth's heritage with parents immigrating from Mexico and her love of Pre-Columbian Mexican art.

The facing scene shows Ruth at work in her Exxon office. The three-dimensional desk in this office was a rectangular prism net that students cut out, folded, and glued together. This was a new technique for most students, one of the studio habits of Hetland, et al. (2007). The upper left of the pop-up scene on the back, shown in the lower left image of Figure 5, shows a fifth grade student placing herself between images of Ruth to show her affinity with this successful woman mathematician.



Figure 5. Student-made dioramas of Hispanic American Ruth Gonzales

Dioramas of Asian American Fan Chung Graham

Several views of student-made dioramas featuring Fan Chung Graham are shown in Figure 6. The front of the diorama depicts a three-dimensional building from the campus of the University of California at San Diego where Fan Chung currently works. The building is the famous Geisel Library, designed by architect William L. Pereira, and named in honor of Audrey and Theodor Seuss Geisel, better known as Dr. Seuss (Langdon, 2014). The inside front scene shows a beach cabana with Fan Chung sitting on a chaise lounge with her pet dog, getting ready to paint a seascape watercolor. She is surrounded by many of her watercolor paintings of the ocean and of famous mathematicians (Chung Graham, 2016).

The facing scene shows her surrounded by various pop-out images of Buckyballs. An example pop-up scene on the rear (near the middle of Figure 6) shows a fifth grade student placing herself between smiling images of Fan Chung with other women mathematicians nearby. Students made watercolor paintings of sunset over the Pacific Ocean in the manner of Fan Chung's paintings. One of these paintings is shown as a backdrop in the middle diorama of Figure 6. Students were able to reflect upon and explain reasons for different aspects of their work, especially the pop-up scene on the back that illustrated the essay they had written as in studio habit 5 of Hetland et al. (2007).



Figure 6. Example student-made dioramas featuring mathematician Fan Chung Graham.

Dioramas of White American Mary Lee Wheat Gray

Example student-made dioramas telling about the life and work of Mary Lee Wheat Gray are shown in Figure 7. The front of the diorama portrays a classical Greek building with four columns like the one on the seal of the American Mathematical Society (American Mathematical Society, 2016), one of the professional mathematics societies with which Mary Lee Wheat Gray was involved. The pillars tell several important roles Mary played during her professional career: mathematician, lawyer, social activist, professor, and mentor. The front inside scene shows Mary at an American Mathematical Society (AMS) Meeting in 1971. She had read in the bylaws that all members were allowed to attend council meetings. Because she was the co-founder and first president of the Association for Women in Mathematics (AWM), she thought she might learn something from attending the meeting. When she was asked to leave, she reminded the all-male group that she was indeed a member and that the

bylaws officially allowed her to attend. The response to her was that there was a gentleman's agreement that only board members could attend council meetings. Mary's now-famous reply was, "I'm not a gentleman. I'm staying" (Riddle, 1996-2016c, para. 3).

The facing scene on the inside of the diorama shows Mary Gray being confronted by a TIAA lawyer during a court case concerning women's retirement inequity. The lawyer remarks that she may know statistics, but she does not know the law. This gave Mary pause to consider his observation; later, she decided to obtain a law degree so that she could better use statistics to fight for social justice through the courts. She graduated summa cum laude with her law degree from Washington College of Law in 1979 and joined the Maryland Bar (Riddle, 1996-2016c). As the project spanned eight months of the year, students persisted in their work, demonstrating inner-directedness as in Hetland et al.'s second studio habit (2007).



Figure 7. Student-made dioramas of Mary Lee Wheat Gray.

Dioramas of African American Kimberly Flagg Sellers

Dioramas made by fifth graders of Kimberly Flagg Sellers are shown in Figure 8. The front of the diorama shows the famous iconic clock tower of Healy Hall at Georgetown University. Kimberly Flagg Sellers is an associate professor in the Department of Mathematics and Statics at Georgetown University. The inside front scene shows Kimberly with University President John DeGioia as she is promoted to Associate Professor with tenure in 2012 (Sellers, 2016). The

facing pop-out scene shows undergraduate Kim with sorority sisters from Alpha Kappa Alpha at the University of Maryland. Because she was the only Black female mathematics major, she turned to a sorority to make friends with other Black college women (University of Maryland, 2012). The pop-up scene for the rear of the diorama, an example shown in the middle of Figure 8, shows a fifth grade student with multiple images of Kimberly Sellers and one image of Pat Courtney Gold. Students expressed strong personal meaning through choice and placement of images in their dioramas as in Hetland et al.'s fourth studio habit (2007).



Figure 8. Dioramas of African American Kimberly Flagg Sellers.

Connections across Racial/ Ethnic Boundaries Shown in Pop-up Scenes

African American students chose a variety of women mathematicians for their pop-up scenes. Some chose an image of each woman mathematician, while others focused on specific women to whom they felt a connection. Many of these scenes showed connections across races. Figure 9 shows example pop-up scenes from African American student dioramas. The arrows point to photos of the girls that they added to the pop-up scenes they designed. The pop-up scenes on the far left shows the student placing herself directly in front of White mathematician Mary Lee Wheat Gray. Both Black and White mathematicians were chosen for her pop-up

scene. The next pop-up scene shows an African American student surrounded by images of all of the women mathematicians. The top middle scene and the far right scene shows an African American student with a variety of minority women mathematicians. The bottom right pop-up scenes shows an African American student with Black mathematicians.

Figure 10 shows example pop-up scenes made by White students. Many included several images of Kimberly Flagg Sellers, probably because of the connection they felt from the video interview with her. Other White students had a variety of women mathematicians in their pop-up scenes. This illustrates that students appreciated the accomplishments of mathematicians regardless of race.



Figure 9. Example pop-ups of African American participants. The arrows point to photos of the students who made the pop-up scenes.



Figure 10. Example pop-ups of White participants. The arrows point to photos of the students who made the pop-up scenes.

Overall Student Reaction to the Project

At about the two-thirds point of the project, students were asked to tell what might be changed to improve the project now or for future similar projects. While eight students responded that they could not think of an aspect of the project they would like to change (e.g., “I don’t really know what to change- there is nothing,” and “I don’t think I would change anything about it.”), eight other students expressed that they wished they could meet two or three times a week to work on the diorama project (e.g., “Maybe longer sessions or come twice a week,” and “Meet three times a week”), and the

remaining eight suggested minor changes such as “maybe cut out something that might not be important” or “spend more time making the dioramas.” These responses indicate that students were satisfied with the way the project was organized and may have even liked to participate more often, showing their task commitment and intrinsic motivation to continue with the project.

Results and Discussion: Impact of Art on Student Motivation

The thematic analysis of student responses to questionnaires administered at the end of lessons and of sentences from student essays resulted in two themes related to the art integration and other themes not directly related to art integration, but rather related to student perceptions of the women mathematicians. The latter themes are analyzed in another paper (Authors, in review). These themes were: equity, gender, and fairness issues, inspirational role models, caring of mathematicians, mathematicians' persistence, mathematicians' love of math, valuing of education, mathematics is helpful to careers, mathematicians can be social, learned spatial skills, valuing of hard work, the sports connection of some mathematicians, interesting mathematics jobs, the full lives of these mathematicians, and racial and cultural diversity. Student responses for the themes discussed in the other paper totaled 477 lines of data. The study described here focuses on two themes not addressed in the other study: the theme of art and mathematics being connected (111 lines of data not included in the other study) and the theme of art being motivating (48 lines of data not included in the other study).

Theme of Art and Mathematics Being Connected

Students were surprised to find that a person can be both a mathematician and an artist. For example, a student wrote that Fan Chung Graham "It surprised me that she likes art, too, and not just math." Another student observed that Gloria Ford Gilmer "uses math in artistic hairstyles;" while another student mentioned she was surprised that Ruth Gonzalez collected Pre-Columbian Mexican art. Students discovered that math can be part of doing art and art can be part of doing math: "Pat Courtney Gold had geometric designs on her baskets;" "She was able to combine the things she loved doing - math and art - to make beautiful baskets;" and "Gloria Ford Gilmer studied hairstyles and found beauty and symmetry. This theme of the realization that mathematics and art can be integrated was the most common theme in all of the data, indicating the impact of this idea on student thinking. Students were elated to learn that math might be related to

one of their favorite activities – art. Several students remarked about their lived experiences in this regard, "I am connected to Fan Chung Graham because we both like math and we are both artists!" and "I love to do art and I am good at math." Many students expressed that they loved working on artistic endeavors in these comment, showing their intrinsic motivation for creating art.

Students also observed that artists can use math to help them with their art. "I've learned that you can use math while doing art," wrote a student. Another student explained that Pat Courtney Gold "made different baskets with patterns on them." Another student commented, "She did art and math at the same time!" One student came to the realization that "Everything involves math, like art." Part of an essay focused on the connection between art and math:

Gloria Ford Gilmer studied pretty and cool hairstyles and made hair a part of math. Gloria Ford Gilmer had to believe that hairstyles were a part of math. Braiding hair is a part of math because the shapes of the parts are tessellations. If the hair was braided with braids arranged in a circle, it would be symmetry.

In these statements, students expressed their realization that math is present in artistic works, allowing them to transfer their enjoyment of art to mathematics, thereby increasing their intrinsic motivation from art to mathematics.

Theme of Art Being Motivating

Other recent investigators (Li et al., 2015; Snyder et al., 2014) have noted that the integration of art into other subjects can be very motivating to students. The art aspects of the diorama project were motivating and inspirational as they provided the freedom to express the self through the work: "Getting to put stuff on and making it on our own unique way;" "I love doing this - it is creative and I love math personally so I enjoy this;" "That you got to do it yourself, design it how you'd like, and it was just fun to do and make." "How much fun and interesting it is to make your own!" These students were expressing the sentiments related to self-actualization in congruence with Linton's (2014) ideas.

Students felt connected to the women mathematicians who were involved with art. "I feel connected to Pat Courtney Gold because she likes to weave baskets and

draw or decorate and I love to do art activities and draw and maybe weave." One student felt inspired to write, "I might like a career in math because math can be involved in art." These statements indicate the positive transference effects when a naturally interesting and intrinsically motivating subject that involves creative expression is integrated into another subject such as mathematics.

Students admired the mathematicians who made works of art. For example, students were inspired by Pat Courtney Gold's expert basket weaving of Sally baskets: "She makes a lot of different Wasco baskets and she was a master in weaving baskets;" and "She puts designs on the baskets - the bird - the condor - because I really like birds - they are a really neat animal." Another student wrote, "Pat Courtney Gold was an artist. She made Sally bags, I want to learn how to make Sally Bags."

Students mentioned that they liked the hands-on aspects of mixing paint and gluing items. "I enjoyed the painting because I like colors and I can see what other colors they make when they mix;" and "Because I like to paint the diorama and gluing stuff on it." Another student expressed,

"How we get to make it so artsy – not a real word, but still."

The art-math integrated project benefited from the intrinsic motivation of creative expression and experimentation, allowing students to become intensely absorbed in the project and to experience *flow* (Csikszentmihalyi, 1990). For example, during the initial diorama painting activities in which students were asked to mix colors to produce a gradient of color on the diorama surfaces, students worked silently and intently for over 40 minutes without interruption. Although their skill levels in mixing paint were undeveloped because of lack of experience, they had learned some new paint-mixing techniques and principles through experimentation and were being challenged to make a smooth gradient of color using their current highest level of skill. The researchers observed that students took their time in painting and mixing colors, working quietly and seeming to enjoy the work immensely as evidenced by facial expressions, groans and surprise when time for the class had expired, and requests to continue with more painting next class. See Figure 11 for a composite image of students working intently on their dioramas near the end of the project.



Figure 11. Composite image of photographs of diverse girls working intently on their dioramas.

Conclusion

Students engaged in the Diverse Women Dioramas Project evidenced the eight studio habits of Hetland et al. (2007). Students developed a sense of which art materials, tools, and techniques to use for different effects as they constructed their dioramas. Task commitment and persistence in this months-long project were shown as students listened carefully to the narrative accompanying the slide shows about the diverse women mathematicians and worked steadily on their dioramas, remarking on how beautiful the dioramas were becoming. Students practiced generating ideas of ways to arrange images on their dioramas, mentally envisioned them, and place items in the arrangements before finally gluing them.

The pop-up scene and accompanying essay, in particular, allowed students to express strong personal meaning through their work, such as favorite women mathematicians or aspects of their lives. Students reflected upon and described reasons for different aspects of their work, presenting the dioramas to other students at their school during a Multicultural Fair and to the researchers at the end of the project. At these times students also participated in evaluating what does and does not work regarding the dioramas. Students stretched their fine motor and spatial construction skills as they assembled the dioramas. Finally, they learned about the collaborative and helpful nature of a community of artists, but also the nature of the mathematics career community in the variety of jobs, the nature of college preparation and advanced degrees, and the social connections enjoyed by professional mathematicians through societies, conferences, paper-writing, and competitions.

As noted in the study by Ceci and Kumar (2016), students' intrinsic motivation was connected with being process-oriented and not overly concerned about the final appearance of their final products, although, without exception, the participants remarked that they were pleased with and proud of their creations. They seemed relaxed and enjoyed the sensory aspects of the arts such as mixing paint colors, applying paint and glue to surfaces, and handling and folding paper items for application to the dioramas.

The most frequent theme of students' responses to questionnaires and essay writings was that art and mathematics can be connected. Students expressed a love for the artistic endeavors of the project, indicating their intrinsic motivation for art and creative expression. This enjoyment was transferred to mathematics as they recognized the enmeshing of mathematics with art, not only in the project, but in everyday life. The diorama construction work was viewed as intrinsically motivating because the creative aspects of the project allowed students to stretch their skills, learn new art techniques of spatial construction, and to experience *flow* as they became absorbed in their work. The high-quality products created by students are evidence of the care and effort that students put into their manufacture. The arts-integrated and studio nature of this project promoted creative production and accompanying intrinsic motivation, allowing students to become eager to learn both information about mathematics careers and three-dimensional art techniques. The positive atmosphere of this studio class and its focus on the challenges of women who rose to leadership roles in mathematics allowed students to make connections to women mathematicians across racial lines based on admiration and realization of similarities.

Implications for Classroom Practice

Students intensely focused on their diorama work. They consistently reported that they found the arts integration aspects of the project very motivating and enjoyed the creative aspects of making the diorama their way. They expressed surprise that art and mathematics can be integrated or connected. This shows that students had experienced little art integration with mathematics previous to this project. This is likely because of a strong focus on preparation for standardized testing in this school district. However, the excitement that accompanied student learning of new art or spatial thinking skills, such as blending colors, making a gradient, making a three-dimensional pop-out scene or pop-up scene was great and could be used to increase student interest in other topics. The authors recommend that more arts-integration be employed to each mathematics and other STEM subjects.

In this project, students became more engaged with mathematics topics because of the creative art activities that were integrated. Integration of the arts into particularly difficult school topics may improve intrinsic motivation and subsequent retention of content. The culminating pop-up choices, self-photographs (selfies), and the accompanying paragraph helped the girls think metacognitively about their ideas concerning diverse female mathematicians in relation to themselves. We encouraged the girls to explicitly make connections between themselves and the mathematicians through the pop-up and the paragraph.

Suggestions for Future Research

The stretching of students' skills in learning three-dimensional construction techniques seemed to be a strong motivator and source of satisfaction in accomplishment during this project. Additionally, spatial thinking skills are important for students to choose and be successful in STEM careers (Uttal & Cohen, 2012). Identification of some difficult STEM concepts from the elementary or middle school curriculum and teaching of them with and without integrated three-dimensional construction skills in a controlled manner may further support integration of the arts into STEM.

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